Price Enhancement, Returns Variability and Supply Response in the U.S. Dairy Sector

by

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Abstract

Dairy producers operating in the U.S. have been protected against market price variability by the Federal price support program for over 35 years. During the late 1970s tax outlays to operate this program grew at a rapid rate. While many authors have addressed the economic implications of the existing dairy price support program few have explicitly considered the relationship between risk aversion, capital investment, milk production, and support price policy in this process. This paper considers the role of uncertainty and risk averse behavior and suggests that these elements are crucial to an economic analysis of the current program and future dairy policy issues.

Keywords: Dairy, risk aversion, asset theory, policy.

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Previous to the mid to late 1930s, the U.S. dairy economy functioned without much formal government price interference. While there were numerous pricing schemes advanced by the private processing sector, these were without explicit government legislative support. Since 1949 the dairy economy has been carefully protected against downward adjustments in market prices and producers gross cash income by a Basic Price Support (BPS) program. An area of interest on the part of agricultural economists and policy makers has been the long-term impact of the price support system on the economic performance of the dairy economy. Heien derived an econometric model of the dairy economy and attempted to measure the cost of the BPS from 1949 to 1974. Dalhgran developed a reactive programming model which was used to measure the price and welfare implications of the BPS in 1978. In a more recent paper, LaFrance and de Gorter develop and estimate a dynamic seven equation econometric model of the dairy sector and investigate the economic impacts associated with a simulated termination of the BPS system.

In the Heien, Dalhgran, and LaFrance and de Gorter studies, as with others conducted prior to these, the models were based on assumed producer behavior under certainty-profit maximization and the conclusions were very similar. These studies have generally concluded that in the absence of the BPS milk prices at the producer and consumer level would have been reduced substantially.

However, sensitivity analysis presented by Dahlgran suggests that if producers are risk averse a small (1.54%) shift in the aggregate U.S. dairy supply curve for milk in response to a support price decline would be sufficient to eliminate the social dead-weight loss of the support program (Dahlgran, p.294). LaFrance and de Gorter observe that "If consumers and/or producers are risk averse, then the stabilizing effects of the price support programs could mitigate the negative effects...and a model that incorporated risk attitudes of producers and consumers explicitly would be useful in dealing with this question." (Lafrance and de Gorter, p.831).

The issue being raised by Dahlgran and LaFrance and de Gorter is whether or not producers are risk averse expected utility maximizers (RA/EUM). If they are then the supply function for milk properly includes a 'risk' variable which would shift the supply function in response to increased uncertainty brought about by a termination of the price support program. This paper presents a theoretical and empirical argument which suggests that the inclusion of a 'risk' variable in the supply function is appropriate. Reasoning from a conceptual model which explicitly incorporates price variability into the optimal decision making process of firms, it is argued that econometric policy models of the U.S. dairy sector need to explicitly consider 'risk' when they are used to investigate the long term economic effects of price support program termination. This is supported by the econometric estimates of a supply and demand model of the dairy sector which explicitly incorporates an empirically defined 'risk' variable.

The paper is presented along the following lines. First, the general theoretical background relating the behavior of the competitive firm to output price variability and covariability is reviewed. Second, a capital asset model derived by Stevens(1974) is presented as a useful basis for conceptualizing the optimization problem of the dairy farm firm under uncertainty and price supports. Third an econometric model of the aggregate U.S. dairy sector is derived and the estimation results are presented. Fourth, the implications of the empirical findings are considered. The last section provides summary and conclusions.

Theoretical Considerations

In the last decade, the economics literature has dealt extensively with the question of the economic behavior of competitive firms under the conditions of uncertainty, risk aversion, and expected utility maximization (Chavas and Pope, Chambers). These models are well developed and only the general conclusions are stated here to save space. Sandmo demonstrated that the impact of a stochastic output price on the production decisions of a RA/EUM firm in a competitive market was to produce an optimally lower output. Hartman demonstrated that under reasonable production function characteristics the demand for capital declines with increases in output price variability. Ishii extended the model of Sandmo to demonstrate that under the assumption of non-increasing absolute risk aversion the impact of increased variability in output price on optimal production levels is negative.

While this theoretical work suggests an interaction between the optimal level of capital and labor chosen by the firm and the variability of output price it does not address the question of the impact of an minimum price support on these decisions. Eeckhoudt and Hansen consider the theoretical impact of imposing minimum price floors on the behavior of a RA/EUM competitive firm. The imposition of such floors is equivalent to market intervention in the form of a support price provision as is used in the U.S. dairy industry. Eeckhoudt and Hansen derive three significant hypotheses which are central to the questions addressed in this paper. These are 1) the impact of imposing a minimum price onto a stochastic output price distribution is to increase the firms optimal production level, 2) a decrease (increase) in the level of the minimum price once established decreases (increases) the level of production for the firm, and 3) an increase in output price variability results in a decrease in the optimal production level of the firm.

These impacts are a result of two factors. First, the minimum price policy itself increases the firms expected market price by truncating the price distribution. This means that any amount of price support, even if it is small, which truncates the tail of the price distribution will shift the mean of the distribution and increase the expected price.[1] Second, the minimum price reduces the expected market price variance faced by the firm.[2] In deriving these hypotheses Eeckhoudt and Hansen work from a model which evaluates a change from a non-truncated price distribution to a truncated one. This does not consider what occurs as an already truncated distribution is modified in a marginal manner. Meyer and Ormiston extend the Eeckhoudt and Hansen results by showing that the same general hypotheses follow from 'strong increases in risk' and not only from 'no-risk to risk' situations.[3]

This conceptual work provides a basis for suggesting that these general models apply to many U.S. agricultural sectors and particularly the U.S. dairy sector. As stated above, the BPS system operates essentially as a minimum price floor scheme. Dairy producers are likely to take into account modifications in their expectations of output price and the stability of market price as they make long-term investment decisions.

A limitation of applying the conceptual models by Sandmo, Eeckhoudt and Hansen, and others, to the situation face by the dairy farm firm is that they all are derived from the standpoint that the firm focuses exclusively on a single product without any consideration of alternative market opportunities. What is required is a more specific conceptual model which incorporates uncertainty induced by a stochastic market price but also incorporates the covariability of the firms output price with alternative production opportunities.

A Capital/Asset Model of the Firm

Stevens(1974) derived a portfolio investment model which he extends to model of a neoclassical firm operating in a competitive market environment wherein the firm chooses optimal levels of capital stock and labor under conditions of output price uncertainty. The key distinction of the Stevens approach is that it characterizes the firm as a portfolio manager which attempts to maximize the present value of the dividends which flow from a selected portfolio of assets. Stevens(1974) extends the Lintner capital asset model to the classical firm by demonstrating the equivalence of a flow of dividends and firm net income per period.

In this paper the Stevens(1974) model is applied to the market situation faced by the dairy firm by noting that dairy farmers are actively engaged in allocating investment resources to alternative assets with the objective of maximizing the present value of the firm's cash flow per period. This cash flow is typically the sum of a limited number of cash flows from alternative farming enterprises.

Assume that the dairy farm owner is risk averse and acts to maximize the firms market value V(0) in any period. Also assume that the expected value and variance of return from the farm asset portfolio are the two primary elements of the owners utility function.[4] With this in mind, the value of the firm can be expressed as:

$$(1) \qquad V(0) = \int_0^{\infty} [\, E(p_i Q_i(K_i, L_i) - w_i L_i - q_i(\dot{K}_i + dK_i))$$
$$- m * Var[p_i Q_i(K_i, L_i) - w_i L_i - q_i(\dot{K}_i + dK_i)]$$
$$- m * \sum_{j \neq i} Cov[\{ \pi_i, \pi_j \}] * \exp \{ -\int_o^t r(x)dx \} \, dt$$

where $Cov[\{\pi_i, \pi_j\}]$ is the covariance between profits (π_i) of the i^{th} activity and the j^{th} alternative (π_j).[5] The variables defined for the i,j commodities are: (the subscripts are omitted for notational convenience)

p = selling price of the output,
Q = quantity of final output,
K = real capital stock,
L = quantity of labor input,
q = price of investment goods,
w = real wage rate,
m = the market price of risk,[6]
d = constant rate of depreciation,

$I \ = (\dot{K} + dK)$ = real gross investment,

$r(x)$ = continuous rate of time discount.

Assuming that the production function for dairy output is nonstochastic and input prices are known the following relationships hold:

$$(2) \qquad CF_i = E(p_i)\ Q_i(K_i,L_i) - w_iL_i - q_i(\dot{K}_i + dK_i),$$

$$(3) \qquad Var(CF_i) = Var(p_i)\ Q(K_i,L_i)^2,$$

$$(4) \qquad Cov(CF_{i,j}) = Cov(p_i,p_j)\ Q_i(K_i,L_i)\ Q_j(K_j,L_j).$$

where CF_i is the firm's cash flow for the ith activity, $Var(CF_i)$ is the variance of CF_i and $Cov(CF_{i,j})$ is the covariance of CF for the ith activity with the jth. Using (2),(3),(4) and replacing K with the expression:[7]

$$(5) \qquad -q(\dot{K}_i + dK_i) = -q_i(-\dot{q}/q + r + d)K,$$

the decision problem faced by the dairy farm firm owner is to maximize (1) by choosing optimal K^* and L^* so as to maximize the expected cash flow from the dairy enterprise adjusted for output price uncertainty:

$$(6) \qquad \text{Max } Z = E(p_i)\ Q_i(K_i,L_i) - w_iL_i - q_i(-\dot{q}/q + r + d)K_i$$
$$- m\ [Var(p_i)\ Q_i(K_i,L_i)^2 + \sum_{j\neq i} Cov(p_i,p_j)\ Q_i()\ Q_j()]\ .$$

where $Q_i()$, $Q_j()$ are shorthand notation for the functions in K and L. The first order conditions for optimal capital and labor stocks are given by (7) and (8):

$$(7) \quad E(p_i)\ \delta Q_i/\delta K_i - q_i(\dot{q}/q+r+d) - 2m\ Var(p_i)Q_i(\delta Q_i/\delta K_i) - m * \sum_{j\neq i} Cov(p_i,p_j)\ Q_j(\delta Q_i/\delta K_i) = 0,$$

and

$$(8) \quad E(p_i)\ \delta Q_i/\delta L_i - w_i - 2m\ Var(p_i)Q_i(\delta Q_i/\delta L_i) - m * \sum_{j\neq i} Cov(p_i,p_j)\ Q_j(\delta Q_i/\delta L_i) = 0,$$

Assuming that the milk production function is a linearly homogeneous power production function of the form:

$$(9) \quad Q_i = A * K_i^a * L_i^{(1-a)}$$

(7) and (8) can be expressed as:

$$(10) \quad K^* = \frac{a\ A\ [\ E(p_i) - m * \sum_{j\neq i} Cov(p_i,p_j)\ Q_j]\ B\ D}{2m\ Var(p_i)\ a\ A^2\ B^{2(1-a)}}$$

$$(11) \quad L^* = [(1-a)/a][q(-\dot{q}/q + r + d)/w]\ K^*$$

with $\quad B = [q(-\dot{q}/q + r + d)(1-a)]/wa$

and $\quad D = -q(-\dot{q}/q + r + d).$

The optimal capital stock, K^*, for the dairy farm firm is a function of the expected price of output, the variance of output price, and the covariance of output price with an alternative output price p_j.

Capital stock is positively related to expected price and inversely related to both sources of uncertainty. A dairy producer who experiences an increase in uncertainty associated with i) an increase in the uncertainty of output price and/or ii) an increase in the covariability of the dairy output price with another alternative output price, will choose a smaller capital stock for dairy.[8]

Model

The following simultaneous equation system was selected to characterize the U.S. domestic dairy economy. The demand side of the model represents aggregate milk demand and is captured in a single equation rather than separate equations for fluid and manufacturing demand. The supply side is captured by a multiplicative stock of cows and yield per cow relationship which together give total domestic production. The model is closed by an equilibrium condition. Empirical definitions for each variable are considered in the subsequent section. The following equations characterize the aggregate U.S. dairy economy:

<u>Stock of Dairy Cows</u>

(12) $C^s(t) = h(\ EP^m(t),\ P^c(t-1),\ P^g(t),\ \sigma^r(t),\ \Delta C^s(t-2),\ u_1(t)),$

<u>Yield per Cow</u>

(13) $Y(t) = l(\ EP^m(t),\ Y(t-1),\ u_2(t)),$

Production

(14) $Q^{m}(t) = C^{s}(t) * Y(t)$,

Aggregate Milk Demand

(15) $Q^{md}(t) = g(\ P^{m}(t),\ I(t),\ PI^{s}(t),\ Q^{md}(t-1),\ u_3(t))$,

Net Commercial Removals

(16) $R^{c}(t) = k(\ \Delta P^{m}(t-1),\ R^{c}(t-1),\ R^{c}(t-2),\ u_4(t))$,

Market Equilibrium

(17) $Q^{md}(t) + R^{c}(t) + R^{e}(t) + R^{g}(t) + R^{f}(t) = Q^{m}(t)$

where: (the time reference is indicative of the period)

$C^{s}(t)$ = average number of producing milk cows on dairy farms,

$EP^{m}(t)$ = a proxy for the expected price of milk,

$\sigma^{r}(t)$ = a proxy for the level of 'risk' in dairy returns relative to crop production returns,

$P^{g}(t)$ = the nominal price of 16% dairy ration per cwt.,

$P^{c}(t-1)$ = the price of cull cows,

$\Delta C^{s}(t-2)$ = the change in the number of dairy cows from period (t-2) to (t-1),

$Y(t)$ = the U.S. average yield per dairy cow,

$Q^{m}(t)$ = the domestic production of milk in the United States on a fluid equivalent basis,

$Q^{md}(t)$ = the aggregate demand for milk in the U.S. on a fluid equivalent basis,

$I(t)$ = the level of nominal disposable income in the United States,

$PI^{s}(t)$ = a Divisia price index of nonalcoholic beverages (excluding milk), non-dairy fats and oils, and meats, poultry and fish products, 1967=100,

$R^{c}(t)$ = the level of net commercial stocks,

$\Delta P^{m}(t-1)$ = the change in $P^{m}(t)$ from period (t-2) to (t-1),

$u_i(t)$ = stochastic disturbance terms.

Expected market price, EP^{m}, in the stock of cows equation is proxied by a two-step estimation procedure which replaces EP^{m} with the least squares estimate of the all wholesale milk price conditioned on the entire set of exogenous variables in the model (Turkington). The high positive colinearity between the individual substitute price series, nonalcoholic beverages, non-dairy fats and oils, and meat, poultry, and fish, necessitates their combined effect be measured by a consumption weighted index of all the price series. A Divisia Index was constructed from the individual price and consumption series for nonalcoholic beverages, nondairy fats and oils, and meats, poultry and fish, and used as a proxy for changing substitute prices.[9] An empirical definition for $\sigma^{r}(t)$ is considered in detail in the next section.

The model is closed by the equilibrium condition setting domestic milk production $Q^m(t)$ equal to total commercial demand, $Q^{md}(t)$, plus net commercial stocks, $R^c(t)$, net commercial exports, $R^e(t)$, net government removals, $R^g(t)$, and on-farm use, $R^f(t)$. $R^e(t)$ and $R^f(t)$ are taken as being exogenously determined in this model. Net government removals becomes the residual after market demands are subtracted from domestic production.

Empirical Measurement of Uncertainty

Traditionally stochastic elements are introduced into theoretical economic models by specifying one or more of the driving variables to be represented by a random variable. The random variable is assumed to be known up to the central moments of it's underlying distribution. In the case of the theoretical economic model presented in this paper, uncertainty was introduced in the form of the expected value, variance and covariance of output prices. Higher moments of the price distribution do not enter into the conceptual model because of the assumption that this variable is distributed normally. Typically, this randomness imparted to the first and second order conditions for optimal behavior by the stochastic price variable is termed 'risk'. There is little agreement as to the appropriateness of this equivalence between uncertainty and 'risk' (Brennan, Thraen and Hammond, Traill, Wann and Fletcher). The difficulty lies in specifying an empirically satisfying proxy for the conceptual notion of uncertainty or 'risk'.

The definition adopted in this study is that uncertainty or 'risk', in an empirical sense, can be proxied as the error in forecasting the level and direction of cash flow $CF_i(t)$ in the next period. It is assumed that producers form an expectation of the level of next periods cash flow based on a moving average formulation involving past information. The concept also reflects the idea that recent information carries more weight that past information. To the extent that the actual cash flow next period deviates from that which was expected 'risk' is incurred.

The 'risk' variable, $\sigma^d(t)$, for dairy returns is measured as a weighted three period moving variance of past gross dairy returns deflated by the average gross returns over the preceding three periods. Deflating by average gross returns expresses the variance relative to the level of average gross returns. Because we are working with aggregate market data and are assuming that dairy producers know their individual levels of production, gross income to dairying is used as the indicator of variance or 'risk' and not market price alone.[10] Specifically this 'risk' proxy $\sigma^d(t)$ for dairy is derived as:

$$(18) \qquad \overline{DR}(t) = 1/3 \sum_{i=1}^{3} DR(t-i)$$

$$(19) \qquad \sigma^d(t) = 1/\overline{DR}(t) \; \{ \sum_{i=1}^{3} (DR(t-i) - \overline{DR}(t-i))^2 * \alpha_i \},$$

(20) α_i, for i = 1,2,3 are 1/2, 1/3, and 1/6 respectively.

where $\overline{DR}(t)$ is the moving average of cash returns over the last three periods, DR(t-i) is the gross returns to dairy in the period (t-i), $\sigma^d(t)$ is the weighted moving average variance of gross returns to U.S. dairying, and α_i are the weights for each period.[11] An equivalently defined 'risk' variable $\sigma^c(t)$ is derived for U.S. crops as the alternative economic activity.

In order to capture the relative variation of dairy to crop returns, the 'risk' variable specified in the estimated econometric model is defined as the ratio of $\sigma^c(t)$ to $\sigma^d(t)$:

(21) $\sigma^r(t) = \sigma^c(t) / \sigma^d(t)$

As can be seen from (19) and (21), an increase in $\sigma^r(t)$ can come about by either a reduction in the variance of dairy returns relative to crops or an increase in dairy returns relative to crops, ceterus paribus. Either type of change would be expected to increase United States dairy output as resources are shifted to milk production.

Estimation and Statistical Results

The estimated model parameters and their related statistics are reported in Table 1. The use of a stock of cows equation and a yield equation introduces nonlinearity into the model (Kelejian). To obtain consistent parameter estimates the model was estimated by nonlinear two stage least squares. All price and income data are in nominal dollars.

Data on milk production, dairy cow stocks, milk prices, feed prices, cull cow prices, milk demand, and commercial milk stocks were obtained from Dairy Outlook and Situation Report, USDA, ERS, April and December issues, 1980 to 1986. Data on wholesale price indexes for nonalcoholic beverages, non-dairy fats and oils, and meats, poultry and fish, were obtained from Food Consumption, Prices, and Expenditures, USDA, ERS SB #713. Data on gross returns to dairy and crops and nominal disposable personal income were obtained from Agricultural Statistics, annual issues 1979 to 1986.

TABLE 1: Econometric Model for the Dairy Economy 1964 - 1983: Nonlinear Two-Stage Least Squares

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Stock of Dairy Cows Equation:

$$C^s(t) = \underset{(6.84)}{14388.06} + \underset{(2.76)}{14.49}\ EP^m(t) + \underset{(3.30)}{77.89}\ \sigma^r(t) - \underset{(2.91)}{27.40}\ P^g(t)$$

$$- \underset{(-1.62)}{1.43}\ P^c(t-1) - \underset{(-2.37)}{2.76}\ \Delta C^s(t-2)$$

ADJ-R^2 = 0.72 Durbin-Watson = 1.55 $"t"_{14,.05}$ = 1.76
DF = 14 SEE = 768.35

Yield Per Cow Equation:

$$Y(t) = \underset{(2.93)}{1.58} + \underset{(10.48)}{0.811}\ Y(t-1) + \underset{(2.19)}{0.00068}\ EP^m(t)$$

ADJ-R^2 = 0.99 Durbin-Watson "h" = 0.0238
DF = 17 SEE = 0.141 $"t"_{17,.05}$ = 1.74

Aggregate Milk Demand Equation:

$$Q^{md}(t) = \underset{(0.86)}{35963.8} - \underset{(-2.00)}{25.07}\ P^m(t) + \underset{(2.07)}{17.04}\ I(t) + \underset{(0.297)}{74.12}\ PI^s(t)$$

$$+ \underset{(2.96)}{0.645}\ Q^{md}(t-1)$$

ADJ-R^2 = 0.84 Durbin-Watson "h" = 0.05
DF= 15 SEE = 2433.46 $"t"_{15,.05}$ = 1.75

Net Commercial Removals

$$R^c(t) = \underset{(-3.95)}{-501.68} + \underset{(6.15)}{12.20}\ \Delta P^m(t-1) - \underset{(-5.66)}{0.69}\ R^c(t-1) - \underset{(-5.12)}{0.65}\ R^c(t-2)$$

ADJ-R^2 = 0.77 Durbin-Watson "h" = 0.146
DF = 16 SEE = 384.68 $"t"_{16,.05}$ = 1.75

-t-values are in parentheses, "h" is the Durbin test for serial correlation with lagged dependent variables.
-SEE is the standard error of the regression.

This model provides a good statistical explanation of the variability in the domestic supply of and demand for milk in the U.S. market. The estimated parameters exhibit the expected signs and are statistically significant at the 0.05 level in one tailed tests with the exception of the Divisia price index for substitutes. While significant substitution from butter to margarine occurred in the 1940's and 1950's, the percapita consumption of margarine has stabilized at approximately 11 pounds over the period of this study. In a recent study Huang provides cross-price elasticity estimates from a complete demand system for dairy products versus a large number of other food commodities. A review of these estimates reveals that dairy products are substitutes for one another, but as an aggregate commodity there are not many significant substitute products.

The supply and demand elasticities measured at the mean values of the data are given in table 2. The elasticities are calculated relative to total milk production and total milk demand. The estimated supply elasticity with respect to expected milk price is 1.15. Feed price elasticity is -0.6 and the cull cow price elasticity is -0.15. These estimates seem reasonable in comparison to estimates reported in previous studies (e.g., Chavas and Klemme, and Chen, et.al.).

Table 2: Estimated Supply and Demand Elasticities

Elasticities derived from the Dairy Model:

SUPPLY:	$EP^m(t)$	$\sigma^r(t)$	$P^g(t)$	$P^c(t-1)$
Q^s:	(1.15)	(0.069)	(-0.60)	(-0.15)

DEMAND:	$P^m(t)$	$I(t)$	$PI^s(t)$
Q^d:	(-0.17)	(0.16)	n/r

Elasticities derived at the means of the variables.
n/r: elasticity not reported due to the relatively large standard error of the estimate.

Elasticity of 'risk' $\sigma^r(t)$

The equation of specific interest is the stock of dairy cows. The estimated parameters are significant at the 0.05 level in one tailed tests. The stock of cows increases with higher expected milk prices and is decreased by increases in concentrate grain prices or cull cow prices. 'Risk' adjusted relative level of returns in dairying (σ^r) is statistically significant in explaining the level of dairy cow capital stock. The positive sign indicates that declines in the variability of dairy gross returns relative to the variability in gross returns to crop production increases the supply of milk by shifting the demand schedule for dairy cows.

The derived elasticity for σ^r is +0.069. A 1% increase in relative 'risk' would result in a 0.069% reduction in aggregate milk production. This is a reasonable estimate given that empirically derived 'risk' elasticities have generally been small in magnitude. While a direct comparison of this elasticity estimate with that of other researchers was not available, this value is consistent with 'risk' elasticity values obtained by Estes, Blakeslee, and Mittelhammer in their investigation of potatoes (.005 to .085), Ryan in his analysis of Pinto beans (.09), and Lin in his study of wheat (.06).

The empirical results imply that dairy producers are sensitive to the level of relative income variability. The termination of the price support program would have to increase relative dairy 'risk' by 23% from it's mean level to achieve the 1.5% reduction in supply considered by Dahlgran. While it seems reasonable that a complete elimination of the support program as considered by most authors would achieve this level of increased instability there is little research upon which to decide this question. In those studies which have considered the issue of stability, the research generally points to increased price and production instability. Thraen and Hammond conclude that the elimination of the support program would result in increased market price and production variability. Hallberg, using a dynamic econometric model, reports a substantial increase in market price variability upon elimination of the support program. LaFrance and de Gorter note that "the simulated competitive prices appear to see-saw up and down over the period 1965-71, suggesting a short-run cobweb type instability in the dairy market".

Concluding Remarks

The conceptual model presented and empirical systems model estimated for this paper suggest that 'risk' considerations should be accounted for in policy models of the U.S. dairy sector. The price support program was implemented to insulate producers from a substantial amount of market price and income risk for the purpose of stimulating milk production. This modifies producer behavior toward optimal levels of capital and labor and production.

While past studies have briefly considered the possibility that accounting for uncertainty would modify their conclusions, this uncertainty has not been explicitly incorporated into their estimated models. Viewing the dairy producer as a risk averse decision maker maximizing an expected utility function introduces uncertainty or 'risk' directly into the optimal conditions for capital and labor use. Estimation of an econometric model which uses relative gross returns variability as a proxy for this uncertainty suggests that 'risk' does shift the supply function for milk.

The recognition that 'risk' exhibits measurable impacts on the production of milk raises the policy question of whether or not the shift in production brought about by an elimination of the price support program would be sufficient to substantially reduce or possibly eliminate the deadweight loss attributed to the price support program. Recent and past studies which have measured the welfare impacts of the price support program have not addressed this issue. An analysis of the social cost of the price support system would have to account for changes in the behavior of σ^r over time. This paper has not specifically considered the welfare effects with returns variability accounted for in the simulation. This is a line of inquiry that needs to be undertaken in future research.

Notes

1. If the original price distribution is assumed to be Normal the effect of the price floor is to alter this distribution to be a Truncated-Normal distribution. This leaves the shape of the distribution unaltered except for a stacking of probability mass at the truncation point. This is the assumption followed by Eeckhoudt and Hansen and is generally found in other published literature on the subject. The question of whether or not the truncation of the price distribution may in fact modify the price distribution to be something other than Truncated-Normal is not considered in this paper.

2. Even in the event that the price policy includes a floor and a ceiling, operating in a manner which truncates the tails of the price distribution leaving the expected price unchanged, the reduction in variance will increase the optimal level of production for the risk averse firm.

3. Meyer and Ormiston define "strong increase in risk" as a transfer of probability mass from locations where it was initially distributed, to points at or to the left or the right of the endpoints of the interval over which the original distribution was defined. This result is important because it suggests that a firm which is facing some price variance even with an existing lower and/or upper bound on the distribution will react to a marginal increase in the variance brought about by a shift in the price bounds at the margin. This definition is a subset of the set of the Rothschild and Stiglitz definitions of increases in risk and includes increases in risk from a nonrandom setting as special cases.

4. This requires the assumption that the utility function is either quadratic or that the returns are normally distributed. The assumption of normality seems to be more reasonable.

5. All variables are implicitly referenced by t with the actual subscript omitted for notational convenience. The subscripts i,j refer to alternative commodities, with the i^{th} being dairying and the j^{th} an alternative to dairying.

6. Stevens defines the market price of risk as that discount rate which prevails in a competitive capital market for multiperiod expenditures.

7. The K is integrated out so that the firm's decision problem is no longer temporally dependent. The firm maximizes (1) by choosing optimal capital and labor in each time period, (Stevens,1973, Appendix B).

8. The same conclusion does not hold for optimal labor use. L^* depends on K^* but from (11) is only indirectly responsive to the moments of the output price distribution.

9. The Divisia index is a continuous time statistical index number. The index used in this analysis is a discrete-time approximation to the continuous case. As a chain-linked index it provides one of the best methods for aggregating price series for different commodities. The price and quantity components of the index constructed for this study are: i) fats and oils (nondairy), ii) citrus and noncitrus fruit juices (chilled and concentrate), iii) coffee, iv) soft drinks, and v) red meats, poultry and fish. The interested reader should consult Layard and Walters, pp.156-159 for more detail on the construction of indexes and the appropriateness of the Divisia index.

10. Gross income includes both cash farm receipts and government payments in the form of net loans and deficiency payments in the case of crops.

11. The weight structure reflects the assumption that the most recent information has the greatest influence on decisions and that the past information is totally discounted after three periods. Actual lag weights were arrived at by trying various lag structures and selecting that structure which performed the best statistically.

REFERENCES

Brennan, J.P., "The Representation of Risk in Econometric Models of Supply: Some Observations," Australian Journal of Agricultural Economics, August(1982):151-156.

Chambers, R., " Relevance of Duality Theory to the Practicing Agricultural Economist: Discussion," Western Journal of Agricultural Economics, Vol.7,(1982):373-378.

Chavas, J.P., and R. Klemme, "Aggregate Milk Supply Response and Investment Behavior on U.S. Dairy Farms", American Journal of Agricultural Economics, Vol.68,(1986):55-66.

Chavas, J.P., and R. Pope, "Hedging and Production Decisions Under a Linear Mean-Variance Preference Function," Western Journal of Agricultural Economics, Vol.7,(1982):99-110.

Chen, D., R. Courtney, and A. Schmitz, "A Polynomial Lag Formulation of Milk Production Response", American Journal of Agricultural Economics, Vol.54,(1972):77-83.

Dahlgran, R. A., "Welfare Costs and Interregional Income Transfers Due to Regulation of the U.S. Dairy Markets," American Journal of Agricultural Economics, Vol.62,(1980):288-96.

Eeckhoudt, L., and P. Hansen, "Minimum and Maximum Prices, Uncertainty, and the Theory of the Competitive Firm", American Economic Review, Vol. 70.,(1980):1064-1068.

Estes, E., L. Blakeslee, and R. C. Mittelhammer, "Regional and National Impacts of Expanded Pacific Northwest Potato Production," Western Journal of Agricultural Economics, Vol.7,(1982):239-252.

Hallberg, M. C., "Stability in the U.S. Dairy Industry Without Government Regulations?", Agric. Econ. and Rural Soc., Pennsylvania State University, Staff Paper No.37(1980):November.

Hartman, R., "Factor Demand with Output Price Uncertainty", American Economic Review, Vol. 66., No. 4., (1976):675-681.

Heien, D., "Cost of U.S Dairy Price Support Program, 1949-74", Review of Economics and Statistics, Vol.59,(1974):1-8.

Huang, K., U.S. Demand for Food: A Complete System of Price and Income Effects, U.S. Department of Agriculture, Economic Research Service, Technical Bulletin No. 1714,(1985):December.

Ishii, Y., "On the Theory of the Competitive Firm Under Price Uncertainty: Note", American Economic Review, Vol. 67,(1977):768-769.

Kelejian, H. H., "Two Stage Least Squares and Econometric Models Linear in the Parameters but Nonlinear in the Endogenous Variables", Journal of the American Statistical Association, Vol.66,(1971):373-374.

Layard, P.R.G., and A.A. Walters, Microeconomic Theory, McGraw Hill Book Company, 1978.

Lin, W., "Measuring Aggregate Supply Response Under Instability," American Journal of Agricultural Economics, 59(1977):903-7.

Lintner, J., "The Valuation of Risk Assets and the Selection of Risky Investments in Stock Portfolios and Capital Budgets," Review of Economics and Statistics,Vol.47,(1965):13-37.

LaFrance,J.T., and H. de Gorter, "Regulation in a Dynamic Market: The United States Dairy Industry, American Journal of Agricultural Economics, Vol.67,(1985):821-832.

Meyer, J., and M. Ormiston, "Strong Increases in 'Risk' and Their Comparative Statics", International Economic Review, Vol.26,(1985):425-38.

Rothschild, M., and J. Stiglitz, "Increasing Risk I: A Definition," Journal of Economic Theory, Vol.2,(1970):225-243.

Ryan, T.J., "Supply Response to Risk: The Case of U.S. Pinto Beans," Western Journal of Agricultural Economics, Vol.2(1977):35-43.

Sandmo, A., "On the Theory of the Competitive Firm Under Price Uncertainty", American Economic Review, Vol. 61,(1971):65-73.

Stevens, G.V.G., "On the Impact of Uncertainty on the Value and Investment of the Neoclassical Firm," American Economic Review, Vol.64,(1974):319-336.

_______________, "On the Value of the Firm, Discounting, and Optimal Investment Under Uncertainty," special studies paper 26.,Federal Reserve Board,(1973), App.B.

Thraen, C.S., and J.W. Hammond, Price Support, Risk Aversion and U.S. Dairy Policy: An Alternative Perspective on Long-Term Impacts, Economic Report ER83-9, Department of Agricultural and Applied Economics, University of Minnesota.(1983).

Traill, B., "Risk Variables in Econometric Supply Models", Journal of Agricultural Economics, (1978):53-61.

Turkington, D.A., "A Note on Two-Stage Least Squares, Three-Stage Least Squares and Maximum Likelihood Estimation in an Expectations Model," International Economic Review, Vol.26(1985):507-10.

United States Department of Agriculture, Economic Research Service, Dairy Outlook and Situation Report, April and December Issues, 1980 - 86.

United States Department of Agriculture, Economic Research Service, Food Consumption, Prices, and Expenditures: 1963-83, Statistical Bulletin No. 713,(1984):November.

United States Department of Agriculture, Agricultural Statistics, annual issues, 1979-86.

Wann, J.J., and S. M. Fletcher, "Alternative Representations of Risk in Econometric Models of Supply: A Case of Soybeans in the Southern Region", Unpublished paper presented at the AAEA Meetings, Ames, Iowa, (1985).